Reproduced by

AIR DOCUMENTS DIVISION

TECHNICAL INTELLIGENCE

HEADQUARTERS AIR MATERIEL COMMAND

WRIGHT FIELD, DAYTON, OHIO

19980121 131

DTIC QUALITY INSPECTED 3

The U.S. GOVERNMENT

IS ABSOLVED

FROM ANY LITIGATION WHICH MAY ENSUE FROM THE CONTRACTORS INFRINGING ON THE FOREIGN PATENT RIGHTS WHICH MAY BE INVOLVED.

DTIC QUALITY INSPECTED 3

TITLE: N-300 Equipment for Measuring Feed-Through and other Characteristics of APN-1 Altimeter Antennas	ATI- 27804
AUTHOR(S): Raburn, Louis	REVISION (None)
ORIGINATING AGENCY: Electronics Research, Inc., Evansville, Ind.	ORIG. AGENCY NO. RN-30k
PUBLISHED BY: (Same)	PUBLISHING AGENCY NO. (Same)

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
Sept '46	Unclass.	U.S.	Eng.	47	photo, diagr, graph

ABSTRACT:

A description is given of special test equipment and techniques developed for obtaining satisfactory drop-out performance with slot antennas. The measuring equipment consists of a modified APN-1 altimeter set and a group of special attenuator pads, r-f cables, and r-f fittings. This equipment will measure the magnitude and path length of all the important signals, and also the feed through attenuation between the two antennas. Bench checks were made with the equipment and the results obtained proved to be accurate enough for all practical purposes.

DISTRIBUTION: Copies of this report obtainable from Air Documents Division; Attn: MCIDXD

DIVISION: Electronics (3) 8	SUBJECT HEADINGS: Antenna slots - Radiation (11030)
SECTION: Antennas (9) 1	
ATI SHEET NO.: R-3-9-65	

REEL — C

1134

A.T.I.

27804

REPRODUCTION QUALITY NOTICE

This document is the best quality available. The copy furnished to DTIC contained pages that may have the following quality problems:

- Pages smaller or larger than normal.
- Pages with background color or light colored printing.
- Pages with small type or poor printing; and or
- Pages with continuous tone material or color photographs.

Due to various output media available these conditions may or may not cause poor legibility in the microfiche or hardcopy output you receive.

☐ If this block is checked, the copy furnished to DTIC contained pages with color printing, that when reproduced in Black and White, may change detail of the original copy.

UNCLASSIFIED

N-390 Equipment for Measuring Feed-Through and other Characteristics of APN-1 Altimeter Antennas

27604

Raburn, Louis

(None)

Electronics Research, Inc., Evansville, Ind.

(Same)

RN-30k

(Same)

Sept '48 Unclass. U.S. Eng. 47 photo, diagr, graph

A description is given of special test equipment and techniques developed for obtaining satisfactory drop-out performance with slot antennas. The measuring equipment consists of a modified APN-1 altimeter set and a group of special attenuator pads, r-f cables, addl r-f fittings. This equipment will measure the magnitude and path length of all the important signals, and also the feed through attenuation between the two antennas. Bench checks were made with the equipment and the results obtained proved to be accurate enough for all practical purposes.

Copies of this report obtainable from Air Documents Division; Attn: MCIDXD

Electronics (3)
Antennas (9)

Antenna slots - Radiation (11030)

R-3-9

Air Documents Division, T-2
AMC, Wright Field
Microfilm No.
RC-1134 F27604

N-300 EQUIPMENT FOR MEASURING FEED

THROUGH AND OTHER CHARACTERISTICS

OF APN-1 ALTIMETER ANTENNAS

(REPORT N-301)

ELECTRONICS RESEARCH, INC.
EVANSVILLE, INDIANA
CONSULTING ENGINEERS

No 27804

N-300 EQUIPMENT FOR MEASURING FEED-THROUGH AND OTHER CHARACTERISTICS OF APN-1 ALTIMETER ANTENNAS

(REPORT N-301)

September 26, 1946

ELECTRONICS RESEARCH, INC.
519 Vine Street
Evansville, Indiana

Report by:

Louis Raburn

Engineering by:

Louis Raburn

CONTENTS

TEXT

CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

Although the APN-1 Absolute Altimeter has been installed successfully in many types of planes during the past few years, little specialized work has been done to measure and evaluate the effect of factors which cause drop-out at low altitudes.* This is because when the APN-1 dipoles are installed on a normal aircraft, it is usually possible to insure adequate drop-outs by observing a few general rules.

The recent trend toward no-drag antennas has made necessary a study of the possibilities of installing in various service aircraft pairs of special slot antennas developed by RCA engineers at Rocky Point, L. I. for the Navy Bureau of Aeronautics. The slot antennas are more favorable than standard dipoles on three counts:

(1) They are flush-mounted and have no drag.

(2) They are not exposed to rough treatment, and can't be bent of shape.

(3) They are not in the wind stream and don't become covered with dust and grease rapidly.

*The accepted definition of drop-out is the condition where the altitude is great enough that the RADIO ALTITUDE needle drops off the peg twice per second.

On the other hand, slot antennas are less favorable on at least four counts:

(1) They usually have more feed-through coupling.

(2) They provide less perfect matches to the cables.

(3) They usually have broader patterns with less directivity toward the ground.

(4) They require a larger ground-plane area.

The slot antenna advantages are all of a mechanical nature and the disadvantages are all of an electrical nature. This means that a slot installation will give poor drop-out performance on both altitude ranges unless the installation is carefully designed in relation to the APN-1 system.

In general, regardless of whether slot or dipole antennas are used, high-range drop-out occurs because the ground-reflected signal is no longer strong enough to operate the indicator. On the other hand, low-range drop-out occurs because the ground signal, while still strong enough to operate the indicator, is overpowered by feed-through and residual signals. Navy Project N-300 was formulated with Electronics Re-

search, Inc. to develop special test equipment and techniques for obtaining satisfactory drop-out performance with slot antennas, but the equipment and techniques are equally valuable for unsatisfactory dipole systems.

Project N-300 includes three sub-projects, and each sub-project will be covered by a separate report. The present sub-project and report cover the development of the N-300 measuring equipment and the explanation of associated measurement techniques. When antenna systems are tested, accurate answers depend upon careful technique at least twice as much as upon precise equipment.

The second sub-project considers the measurement of feed-through and residual signals when dipole and slot antennas are installed on inverted field mock-ups and various types of service aircraft. The third sub-project covers the development of techniques to enable predictions of any given system's drop-out performance.

The theory of operation, antenna installation, and maintenance of the APN-1 system has many unusual features and it is <u>strongly</u> urged that the "Handbook of

Maintenance Instructions for Radio Sets, APN-1,etc.; #AN/08-10-189" be studied before considering the effect of the interfering signals and the predictions of drop-out altitudes. This sub-project originally began with little information besides that in the APN-1 Handbook, but it has been necessary to develop several new theories regarding the performance of certain specific parts of the APN-1 system. This report gives a description of the measurement techniques for all types of data, and it is probable that some parts of the report will prove to be irrelevant for any one problem.

The measuring equipment described in this report consists of a modified APN-1 altimeter set and a group of special attenuator pads, r-f cables, and r-f fittings. The equipment will measure the magnitude and path length of all the important signals, and will measure the feed-through attenuation between the two antennas. It can measure a signal only when it is equal to or stronger than the other signals. This is assured by the test procedures in Section 4.2 and 4.3. In particular, feed-through measurements are made by field tests on inverted mock-ups far from reflecting trees and buildings, and by flight tests on aircraft installations at altitudes in excess of 10,000 feet.

It is natural to speculate about the chances of developing equipment to measure the feed-through of installed antennas on aircraft sitting on the ground. It is hard to imagine an audio signal filter or an r-f shield and choke that could be designed to eliminate the ground reflection signal without disturbing the feed-through signal.

In closing this section, it should be emphasized that data measured with the N-300 equipment must be treated and considered very carefully. This is because of two factors:

1. The 120-cycle fm sweep is approximately sinusoidial and the audio beat signal produced by the detection of the received signal with a sample of the transmitted signal will vary in instantaneous frequency through the range from zero up to a maximum value, even though the received signal has a path of fixed time delay. This variation makes it harder to measure the audio frequency than to measure the number of limiter pulse counts, which is what the altitude indicator actually does. Because the audio frequency changes, the gain of the amplifier changes, making it hard to measure anything but the peak value of whatever appears on the limiter grid.

2. During the field and flight tests, it is not usually possible to eliminate all signals but the one being measured. To enable the use of such impure data, extensive bench checks have been made with the N-300 system to consider the combined effect of two signals of arbitrary magnitudes and frequencies as they produce altimeter and voltmeter readings. The bench checks have suggested the procedure that is given in Section 4.4 and the procedure will give results accurate enough for all practical purposes.

As a final word of caution, measurements on inverted mock-ups will give reliable values for feed-through signals and comparative attenuation, but they will usually give inaccurate values for feed-through path length. This is caused by the gain-change in the audio amplifier, and even with long series antenna cables, the gain for the feed-through signal is low enough that reflections from ground objects distant from the mock-up will be amplified with greater gain and add appreciably to the measured path length.

2.0 DESCRIPTION OF EQUIPMENT

2.1 Modified RT-7/APN-1

The RT-7 unit has been modified as described in Section 6.2. It still requires 28 volts at 3.0 amperes, and fits the associated MT-14/ARN-1 cradle. It retains plug connections for TRANSMITTER ANTENNA, RECEIVER ANTENNA, INDICATOR, and BATTERY INPUT. The disabled plug connections are AUTOMATIC PILOT, LIMIT SWITCH, and LIMIT INDICATOR. Three new plug connections are SIGNAL VOLTMETER, LIMITER GRID, and LIMITER PLATE. The unit is employed with special associated equipment shown in Figures 2 and 4. It has a built in audio vacuum-tube voltmeter that will measure signal voltages and feed-through attenuation with an accuracy of ± 1 db. It will measure feed-through path lengths with an accuracy of ± 6 feet.

2.2 Signal Voltage Meter

The audio signal meter is a peak-reading voltmeter calibrated to indicate signal voltage for the range of 0 to 30 r.m.s. The meter is linear over the entire range, but the final audio amplifier stage tends to saturate in the vicinity of 20 volts r.m.s. (28 volts peak). The lower limit for signal measurements is caused by 2 or 3 volts of shot noise, residual signals, etc.

The meter required must have a 100 micro-ampere movement with 2,000 ohms resistance, and is used with a two-conductor shielded cable fitted with a standard phone plug. It has been found most convenient for mock-up and flight testing to utilize the 100 micro-ampere range of a standard Simpson Model 260 Set Tester, since the tester will also measure the d.c. supply voltage and continuities.

2.3 Standard Antenna Cables

The two ten-foot RG-8/U cables shown in Fig. 2 are used to give 15 feet of "air path" for calibration with the co-axial pad. The two cables may be replaced by a single twenty-foot RG-58/U cable for the sake of compactness.

2.4 Resistor Pads

The N-300 equipment includes three resistor pads constructed from modified Type N fittings as described in Section 6.3 and Figure 8 with the attenuations of 6 db, 12 db, and 20 db. The pads are accurate for any frequency up to 500 megacycles. If the pads are assembled with carefully chosen resistors, they have an accuracy on the order of ±1 db, and if a 440 megacycle signal generator is available, they can be calibrated even more closely.

2.5 Co-Axial Pads

A co-axial attenuator is employed as a very convenient way to insert 60 db of attenuation in series with the standard cables when measuring the calibrating signal voltage. This pad is constructed according to Section 6.4 and Figure 9. It must be calibrated and adjusted by using a 440 megacycle signal generator and receiver, or by direct feed-through signal comparison using the N-300 equipment. In the latter case, it will be necessary to make an extra 20 db resistor pad to provide a total of 58 db of path attenuation when the resistor pads are connected in series for comparison with the 60 db co-ax pad. This latter process can be no more accurate than the calibration accuracy of all the resistor pads.

2.6 R-F Connectors

To make all possible tests, it is necessary to have the following group of fitting adapters:

- 2 Straight adapters with type N jacks, UG-29/U
- 1 Straight adapter with type N plugs, UG-57/U
- 2 Straight adapters for UHF to type N, UG-83/U
- 2 Straight adapters for UHF to type N, UG-146/U

3.0 DESCRIPTION OF THE PROBLEM

Some introductory theory will be included to

make a smooth transition with the APN-1 instruction book.* The APN-1 receiver is a balanced diode detector that feeds audio signals into a three-stage audio amplifier having a compensated frequency response to favor the altitude signal over all the undesired signals. The output goes through a 12SH7 limiter stage, and the limited pulses go to a pulse-counter that makes the altitude indicator and limit indicator read proportional to the pulse frequency, and thus indicate the absolute altitude.

The various types of audio signals that appear on the limiter grid, listed in order of decreasing magnitude, are the following:

(1) The antenna-path signal voltage "E_a" is caused by r-f power that goes from the transmitter to the ground, and is reflected by the ground back to the receiver antenna. It is a voltage measured by the audio voltmeter, but for brevity is called the "Altitude Signal."

(2) The antenna-path signal "E_f" is caused by r-f power that goes from the transmitter antenna to the receiver antenna directly across the skin of the ship. It is called the "Feed-Through Signal."

*Section IV, "Theory of Operation," for Radio Sets APN-1, etc. Handbook of Maintenance Instr., AN-08-10-189.

(3) The residual signal "E_{rc}" is caused by r-f power that is reflected back into the transmitter and receiver antenna cables at the imperfect matches presented by the antennas. It is called the "Residual Cable Signal."

(4) The residual signal "E_{rd}" is caused by unbalance in the fm detector as it is loosely coupled to the fm oscillator. It is called the "Residual Detector Signal."

(5) The antenna-path signal "E_m" is caused by minute r-f arcs across intermittent contacts along the feed-through path plus high-speed changes in the amount of feed-through caused by prop rotation, and so forth. It is called the "Field Modulation Signal," and it causes the most trouble at low altitudes with high-range operation.

(6) A group of residual signals that are usually below the limiter level of 3 volts peak. Included are signals due to audio amplifier shot noise, audio microphonics, ignition noise entering through the d-c supply leads, etc.

"E_a" contains the information about the altitude of the airplane above the ground. The magnitude may vary over the range 5 to 30 volts, and decreases with some power of the altitude, decreases with poor antenna-to-cable matches, and increases directly with the directivity of the antennas in the downward direction. The signal at any given altitude is always stronger on the high altitude range than the low altitude range.

"E_f" is appreciable only when the altimeter operates on the low altitude range, and for this range may vary in magnitude from about twice the limiter level of 2 volts r.m.s. up to the amplifier saturation level of 20 volts r. m. s., depending upon the type of antennas, their location, and the length of the antenna cables.

"E_{rc}" is appreciable only when the altimeter operates on the low altitude range, and for this range may vary in magnitude from a negligible value up to about three times the limiter level, depending upon the antenna mis-match and the length of the antenna cables. Reflections at the receiver antenna usually over-shadow similar reflections at the

transmitter antenna.

"E_{rd}" is appreciable only when the altimeter operates on the low altitude range, and for this range may vary in magnitude from 2 volts up to 6 or 7 volts as the detector becomes unbalanced. For optimum balance, "E_{rd}" may vary a db or so as the line voltage changes from 26 to 30 volts d-c. Because it has an appreciable magnitude on the low range, it is essential to balance carefully the N-300 set as explained in Sec. V.15 of the APN-1 Handbook before making any measurements.

"E_m" and the minor residual signals are negligible for good installations, and since the N-300 project was set up to consider the other signals, little more will be said about these signals.

When one signal at the limiter grid is at least half as strong as the strongest signal, the signal voltmeter will indicate a composite of both, and a test procedure is explained in Section 4.4 with Figure 6 for this situation. When two signals

appear at the limiter grid, the altitude indicator will indicate a composite of both, depending upon the comparative strength of the signals and their path delays. In general, the N-300 equipment is employed to measure signals and path delay lengths only when the signal in question is at least as strong as any of the other known signals at the limiter grid.

Measurements are performed by a comparison process of two steps:

(1) The r-f sensitivity of the N-300 equipment is calibrated by connecting the two standard cables and the 60 db coaxial pad between the TRANSMITTER ANTENNA and RECEIVER ANTENNA jacks. The audio signal voltage measured at the limiter grid by the voltmeter is "E_c," and is called the "Calibrating Signal." "E_c" will be about 15 volts, and will depend upon the transmitter output, receiver input sensitivity, audio gain, line voltage, etc.

(2) The antenna-path signals are measured by connecting the antenna cables to the TRANSMITTER ANTENNA and RECEIVER ANTENNA jacks. If the signal

exceeds 15 volts, the appropriate resistor pads are inserted in series with the transmitter cable to bring the signal within the range 6 to 15 volts.

When the above two steps have been followed, it is possible to express the signal as the ratio E_x/E_c, or it is possible to calculate a comparative attenuation in db for the path of the measured signal. The calculations are described in Section 4.2 and 4.3 and values of comparative attenuation are very convenient for evaluation purposes since the antenna and altimeter performance are interdependent.

The comparison process <u>does</u> <u>not</u> give the absolute values of attenuation that would be measured by a calibrated 440 Mc signal generator and a 440 Mc am receiver. The audio amplifier has a rising gain vs. frequency response, and the gain is more when amplifying "E_a" or "E_f" than when amplifying "E_c" since the latter usually has the shortest path length.

Because the N-300 measuring process requires special test equipment, it might occasionally be necessary for inter-project liaison, to specify absolute values of attenuation. In this case, it is possible to calculate absolute values by adding to the comparative attenuation figure a conversion factor "G_f" obtained from Figure 5.

4.0 INSTALLATION AND OPERATION

4.1 Installation

The installation of the N-300 test equipment for a long series of flight tests should be made in accordance with Section II of "Handbook of Maintenance Instructions for Radio Sets APN-1,etc." If a mock-up installation is tested, the mechanical work can be greatly simplified.

The N-300 set should be balanced for minimum "E_{rd}" in accordance with Section 5.3 of this report, and adjusted on the bench for the residual delay of the installation to be tested, in accordance with Section V of the Handbook. The N-300 should be installed at the proposed altimeter location, and the antenna, indicator, battery input, and voltmeter cables connected to the N-300 set.

It has been found that UHF connectors introduce appreciable mis-match at 440 Mc, and will increase "E_{rc}" one db or so, depending upon the cable length. For this reason, it is desirable to avoid the connectors where possible when precise measurements are made. The type N connectors employed by the pads introduce no appreciable mis-match at any time.

4.2 Mock-Up Test Procedure

(1) Locate the equipment so it is outside the radiation field of the antennas on the inverted mock-up, and so that the antenna cables need be only as long as those on the proposed aircraft installation. The latter requirement is important because the magnitude of "E_r" and "E_{rc}" increase as the cable lengths increase.

(2) Connect the power and indicator cables to the N-300 set, turn the power switch on, allow the N-300 set to warm up for one minute, and check that the line voltage is within the range 26 to 30 volts.

(3) Connect the UHF plugs of the two 10-foot standard cables to the TRANSMITTER ANTENNA and RECEIVER ANTENNA jacks on the N-300 set. Connect the Type N plugs of the standard cables to the jack ends of separate resistor or co-ax pad combinations, thus terminating both cables in approximately 50 ohms, but not coupled together.*

(4) Plug a grounded jumper wire into the limiter grid tip jack on the front panel to eliminate all signals on the voltmeter. Zero-set the voltmeter by the screw-driver adjustment R-112A, the outer shaft of the LIMIT INDICATOR ADJUSTMENTS, and remove the grounding jumper.

*The resistor pads present 50 ohms only at the jack ends, and for zero "E_{rc}" they are connected with the jacks toward the N-300 set.

The meter zero should be checked occasionally, but a special circuit has been developed employing degeneration that maintains good zero-setting.

(5) Turn the RANGE switch for low range operation, (4 hundred feet) and adjust, with a screw driver through the hole in the top cover, the balance potentiometer for minimum "E_{rd}" on the voltmeter. The balanced signal is usually in the range 2 to 4 volts, and the balance will change as the line voltage changes.

(6) Connect the 60 db co-ax pad, ("Attenuation of Direct Path, $A_d = 60$ db",) between the two type N plugs of the standard cables. Read the voltmeter for "E_c" and it should be in the range 8 to 16 volts.

(7) Remove the standard cable from the RECEIVER ANTENNA jack and connect the cable from the receiver antenna on the mock-up. Read the voltmeter for "E_{rc}," and it should be in the range 3 to 9 volts, depending upon the type of antennas and length of cables used. If desired, it is possible to measure the "E_{rc}" caused by reflections on the transmitter cable, but they are usually negligible.

(8) Remove the standard cable from the TRANSMITTER ANTENNA jack and connect the cable from the transmitter antenna on the mock-up. Connect in series with the transmitter antenna cable the appropriate resistor pad to bring the meter reading within the linear range 6 to 15 volts. The meter reading is "E_{f+rc}," and is called "Feed-Through Plus Cable Signal." The sum of the pads is "A_f," "Attenuation For Measurement of Feed-Through Signal."

(9) It is possible to read the RADIO ALTITUDE indicator to determine the length of the feed-through path across the skin of the mock-up between the two antennas, but such readings usually are too high because of reflections from trees, buildings, etc., within a half mile of the mock-up. The general trend of the N-300 project has proven that the values of radio path lengths have no development value, and values of path length for attenuation conversion purposes can be measured on the actual mock-up.

(10) Because "E_{rc}" and "E_f" have nearly the same path length, if "E_{f+rc}" is at least twice "E_{rc}," the cable residual signal has negligible effect upon

the feed-through measurement, and "E_{f+rc}" can be considered "E_f." If the "E_{f+rc}" signal is less than twice the "E_{rc}," the value of "E_f" is less than "E_{f+rc}" and to calculate "E_f" the procedure of Section 4.4 must be followed.

(11) The data from steps (6), (8), and (10), can be used to calculate "A_{cf}," "Comparative Attenuation of Feed-Through Path," as follows:

$$A_{cf} = A_d - A_f - 20 \log_{10} (E_f/E_c)$$

The same data can be expressed alternately by the ratio E_f/E_c for any given A_f.

(12) Example of Typical Data and Calculations:

XP4M SLOT MOCK-UP

T_t	T_r	A_d	A_f	Meter Volts	Signal Measured
50	50	-	-	1.5v	E_{rd}
50	Slot	-	-	4.5v	E_{rc}
50	50	60db	-	16.2v	E_c
Slot	Slot	-	6db	9.5	E_{f+rc}

$$\frac{E_{f+rc}}{E_{rc}} = \frac{9.5}{4.5} = 2.1 \quad \therefore \quad E_f = E_{f+rc} = 9.5v$$

$$A_{cf} = A_d - A_f - 20 \log 10 \left(\frac{E_f}{E_c}\right)$$
$$= 60 - 6 - 20 \log 10 (0.58)$$
$$= 58.5 \text{ db, or}$$
$$E_f/E_c = 0.58 \text{ for } A_f = 6 \text{ db}$$

4.3 Flight Test Procedure

(1) - (7)

The first seven steps of the flight test procedure are the same as the first seven steps of the mock-up test procedure in the previous section. They should be performed in excess of 200 above the ground to avoid the effect of ground reflected signals upon "E_{rc}."

(8) - (11)

These steps are performed in the same way as steps 8-11 of the mock-up test procedure. They should be performed at an altitude of at least 10,000 feet above water, or 8,000 feet above land. At these altitudes the "E_a" signal on the low range is too weak to affect the "E_f" readings, but it may add counts and increase the reading of feed-through path length. If there is any suspicion that the "E_a" signal is apprecia-ble, gradually descend several thousand feet in

altitude, and look for increases in the RADIO ALTITUDE.

(12)

When flight-testing altimeter installations, it is very helpful to measure the strength of the "E_{a+f+rc} signal to determine whether poor performance is caused by comparatively strong "E_{rc}" and "E_f," or by comparatively weak "E_a." Because of this reason, it is usually worth-while taking data at altitudes above and below drop-out on both low and high ranges of operation. The data can be most conveniently plotted as graphs of absolute altitude. If it is desired to break down "E_{a+f+rc}" into its separate signal components, the procedure of Section 4.4 can be employed, even though the path length of "E_a" may be much greater than the others. Another N-300 report is being prepared that will go into particular detail about signal values when the APN-1 system is near drop-out.

JRB SLOTS OVER LAKE ERIE

4.3.1 Preliminary Data

T_t	T_r	A_d	A_f	Meter Volts	Signal Measured	Comments
50	50	-	-	2v	E_{rd}	
50	Slot	-	-	7v	E_{rc}	
50	50	60db	-	17v	E_c	
Slot	Slot	-	0db	18v	E_{f+rc}	Taken at 10,000 feet

4.3.2. Altitude Performance Data

	Low Range		Hi Range		
Press Alt.	Meter Volts	Radio Altitude	Meter Volts	E_a/E_c	Radio Altitude
10,000	18	35'	3/2	0.18	PEG/3800
8,000	"	40	3.5	0.20	PEG
6,000	"	60	5.0	0.30	"
4,000	"	100	10.0	0.59	4,000
2,000	"	220	13.0	0.76	2,000
1,500	"	300	15.0	0.88	1,500
1,000	20	Peg	16.0	0.95	1,000

4.3.3. Calculations

$$\frac{E_{f+rc}}{E_{rc}} = \frac{18}{7} = 2.6 \quad \therefore \; E_f = E_{f+rc} = 18_v$$

$$A_{cf} = 60-20 \log_{10} \left(\frac{18}{17}\right) = 59.5 \text{ db}$$

Low range drop-out at 1,000 feet is caused by E_f, and here $E_{a+f}/E_f = 20/18 = 1.1$.

High range drop-out at 10,000 feet is caused by weak E_a, here $E_a = 2$ volts.

4.4 Procedure For Two Signals At Limiter Grid

Because the rate of fm, the audio signal frequency, and the audio signal magnitude continuously change during the fm sweep, it is not possible to write down equations that will give the resultant signal voltage and altitude indications when two signals of different frequency, magnitude and phase are applied to the limiter and voltmeter. A group of bench tests have verified certain general facts, and some of these will be mentioned in this section. Another report of this N-300 series will deal with predicted drop-out conditions, and in that report much more detail regarding this problem will be presented. This section will describe the use of the graph of Figure 6 to sort out two signals when they are present in nearly equal proportions.

Fig. 6 has been prepared for the case where "E_{rc}" is not negligible compared to "E_{f+rc}." The ratio E_{f+rc}/E_{rc} is used to scale from curves the appropriate value of

E_f/E_{f+rc} and E_f/E_{rc}. For example, assume the case:

"E_{rc}" = 4.5v, "E_{f+rc}" = 7.0v, so E_{f+rc}/E_{rc} = 1.56.

Tracing on the curve, E_f/E_{f+rc} = 0.88.

Therefore, "E_f" = 0.88 (E_{f+rc}) = 0.88(7) = 6.4v.

The dependent ratio E_f/E_{rc} is more convenient to use when low values of E_{f+rc}/E_{rc} are considered.

Figure 6 seems to be accurate regardless of the signal frequencies, and it is possible to employ the same procedure in handling flight test data for "E_{f+rc}" and "E_{a+f+rc}" to calculate values of "E_a." When this is done, it is possible to overlook the fact that "E_f" and "E_{rc}" are caused by different paths because path lengths are always nearly the same.

Altimeter drop-out on the low-altitude range occurs when "E_a" has a value in the range 30 to 140 per cent of "E_{f+rc}." The actual ratio of E_a/E_{f+rc} for drop-out depends greatly upon the altitude, and a full discussion of this problem will be deferred until the final report of the series.

4.5 Conversion of Comparative Data to Absolute Data

(1) The value of "A_{cf}" calculated in Section 4.2 and 4.3 is a necessary and sufficient criterion of feed-through for any given APN-1 installation. The magnitude of "E_f" depends not only upon the absolute attenuation "A_{af}" of the feed-through path, but also upon the effective delay length, "L_f" of the feed-through path. For a fixed "A_{af}," if the total length of the antenna cables is changed from one limit to the other, the change in audio signal frequency and amplifier gain will change the magnitude of "E_f" and "A_{cf}" as much as 10 db. In other words, "A_{cf}" completely specifies the amount of feed-through whereas "A_{af}" by itself does not.

Because other groups may have made, in the past, substitution measurements of "A_{af}" using long lengths of antenna cables and variable attenuators, it may be necessary to specify values of "A_{af}" for inter-project liaison reasons. The most accurate way to measure values of "A_{af}" with the N-300 equipment is to employ the reliable substitution process. This process consists in connecting several hundred feet of co-axial cable and a calibrated variable attenuator in series with the antennas having the feed-through. The attenuator

is adjusted to give an "E_f" within the range 6 to 15 volts. The cables and attenuator are then connected in series, and the added attenuation necessary to maintain "E_f" is the "A_{af}" presented by the antennas. The purpose of the long cables is to make the added length of "L_f" and "G_f" negligible.

If it is necessary to convert "A_{cf}" data to "A_{af}" when it is no longer possible to test the actual installation, it can be done by estimating the physical length, "L_f" of the path, including the cable lengths and the radiation path length. The length "L_f" can be employed with the graph of Figure 5 to obtain the "Gain Conversion Factor For Feed-Through Path," "G_f." The conversion is as follows: $A_{af} = A_{cf} + G_f$.

(2) Example of Calculations

Assume the example of Section 4.2 plus an "L_f" of 30 r-f feet. From graph, $G_f = 6$ db; $A_{af} = 58.5 + 6 = 64.5$ db.

The accuracy of the calculation is probably within a db or two. It will be noticed that the conversion graph does not apply for "L_f" less than 16 feet, but this is no particular limitation, since the "L_f" for any actual installation will invariably be more than that. As mentioned before in this report, the RADIO ALTITUDE meter

of the N-300 does not always give reliable readings for "L_f," and it is recommended that for conversion purposes, "L_f" be estimated from the physical installation than measured by the meter.

5.0 MEASUREMENT ERRORS AND PRECAUTIONS

5.1 Stability of Test Equipment

The transmitter power, receiver sensitivity, audio gain, voltmeter calibration, and attenuators, all seem to be stable with vibration and temperature changes. If the battery supply voltage shifts from 26 to 30 volts while comparison readings are taken, the over-all attenuation reading may be affected as much as 2 db. For this reason, it is best to take data only when the battery supply voltage is constant.

5.2 Linearity of Voltmeter

The voltmeter reads the input to the limiter grid accurately within one db over the meter scale 0-30 volts r.m.s. The limiter input signal is not proportional to the received r-f signal at either end of the voltmeter scale. For meter readings less than twice the "E_{rd}," there is masking that keeps the meter from being directly proportional to the signal input. For signals stronger than about 17 volts the amplifier saturates and, in fact, it can not drive up to 30 volts. These two factors provide the limited meter range of 6 to 15 volts with an accuracy of 1.5 db.

5.3 Residual Signal Errors and Balance Procedure

As explained in the previous section, when readings of weak "E_a" and "E_f" are made, it is essential that the detector balance be the best possible. The balance problem is greatly aggravated if the antenna cables are not terminated by antennas that appear like 50 ohms of pure resistance over the entire range 420-460 megacycles. As an example, slot antennas give 6 db more "E_{rc}" than do the standard dipoles, even when the detector is balanced properly. This is due to the fact that if a signal gets on the cable and travels down it, antenna mis-match at the far end will cause a returning signal delayed in time that will operate the FM detector even though it is perfectly balanced against AM interference. Reflections in the transmitter cable are not nearly as serious as comparable ones in the receiver cable, presumably because they must traverse an indirect path through the oscillator-detector mixing signal link whereas reflections in the receiver cable appear directly at the detector. It has been found that APN-1 equipment balanced for use with the dipoles may have an "E_{rc}" 12 db stronger than limiting level when operated with slot antennas and ten foot cables.

The major amount of the "E_{rc}" signal can be eliminated if the r-f circuits of the detector are so adjusted that the least amount of signal from the oscillator-detector mixer link

gets out on the receiver cable. This can be done by adjusting T 102, T 103, and C 141 of the RT-7 with R 114 balanced; a 440 Mc AM receiver, such as the APR-1, connected to the receiver cable; and the proposed antenna connected to the transmitter cable. It may be necessary to readjust slightly T 102, T 103 and C 141 when adjusting R 114 for the minimum signal when the proposed antenna terminates the receiver cable. This adjustment can be best performed with a scope connected to the limiter grid in addition to the signal voltmeter.

In the event a separate AM receiver is not available, the balancing can be done as follows:

1. Set R 114 on resistance balance with an ohmeter.
2. Turn set on, connect transmitter and receiver cables of length similar to those of aircraft installation. Terminate transmitter cable in 50 ohms by co-ax pad, and terminate receiver cable in open or short circuit, whichever gives the most residual signal.
3. Balance C 141, T 103, and T 102 for minimum. Try balance for several fixed positions of C 141.
4. Terminate receiver cable in proposed antenna and balance R 114.

It is desirable to check frequently R 114 to be certain that "E_{rd}" is less than 3 volts when taking data.

Another effect of "E_{rd}" is to add or subtract from the meter readings, depending upon which direction the detector is unbalanced. This makes the reading of small signals doubtful if "E_{rd}" is more than 3 volts.

5.4 Altitude Indicator Errors

If the signal voltage is less than about 12 volts for the low altitude range, the limiter can respond to residual signals that add more pulses and increase the RADIO ALTITUDE reading. For this reason it is desirable to make all altitude indicator readings with the attenuation reduced sufficiently to provide a strong signal to the limiter. When measuring the feed-through of well-designed antenna installations, the signal may be little stronger than the residual signal, even with no added attenuation, and in this case, the indicator may give inaccurate delay lengths due to the effect of residual signals and weak "E_a" signals.

As explained in Section IV .1 (d) of the APN-1 Maintenance Handbook, even with a strong steady signal to the limiter, the indicator may vary ± 3 feet on the 400 foot range and ± 30 feet on the 4000 foot range due to the action of the counting circuits.

6.0 APPENDIX

6.1 List of Symbols

A_a - "Attenuation for Measurement of Altitude Signal"; the sum of the attenuator pads in altitude signal path.

A_d - "Attenuation For Measurement of Direct Signal"; the sum of the attenuator pads in direct coupled path.

A_f - "Attenuation For Measurement of Feed-Through Signal"; the sum of the attenuator pads in feed-through signal path.

A_{af} - "Absolute Attenuation of Feed-Through Signal Path."

A_{cf} - "Comparative Attenuation of Feed-Through Signal Path."

A_{ro} - "Zero Altitude Path Length"; see page 6-1 of APN-1 Maintenance Handbook, AN-08-10-189.

E_a - "Altitude Signal."

E_{a+f} - "Altitude Plus Feed-Through Signal."

E_c - "Calibration Signal."

E_f - "Feed-Through Signal."

E_{f+rc} - "Feed-Through Plus Cable Signal."

E_{rc} - "Residual Cable Signal."

E_{rd} - "Residual Detector Signal."

F_o - "Frequency of Zero Altitude Path Signal"; see page 6-2 of APN-1 Maintenance Handbook, AN-08-10-189.

G_f - "Gain Conversion Factor For Feed-Through Path."

L_f - "Length of Feed-Through Path."

T_r - "Termination of Transmitter Antenna Cable."

T_t - "Termination of Receiver Antenna Cable."

6.2 Modification RT-7/APN-1

The RT-7/APN-1 has four mechanical modifications shown in Fig. 4. A hole is drilled in the top of the dust cover to allow screw-driver adjustment of the detector balance control. A hole is drilled in the front panel to mount the insulated phone jack used with the signal voltmeter. Two holes are drilled in the front panel to mount the insulated tip jacks carrying limiter grid and plate signals.

The circuit modification shown in Fig. 3 uses the tube sockets formerly employed by the limit indicator for the added signal voltmeter. The original 12H6 is retained, but the 12SH7 is replaced by a 12SL7GT, and R112A, the outer-control potentiometer of the Limit Indicator Adjustment is employed as the meter zero set.

6.3 Construction and Calibration of the Resistor Pads

The resistor pads are constructed as shown in Fig. 8 with very short leads. Their accuracy at 440 megacycles is apparently limited by the accuracy with which the resistors are selected on a d-c bridge. The 6 db pad is constructed with two parallel resistors in the

series branch instead of two parallel resistors in the shunt branch to reduce inductance effects. It is not possible to employ a single, adjustable co-ax attenuator to replace all the pads since a non-resonant co-ax attenuator has a minimum insertion attenuation of 30 db.

The resistor pads are checked for calibration by comparison tests with a calibrated signal generator feeding a 440 megacycle AM receiver, or the receiver section of the modified RT-7/APN-1 with the detector unbalanced to respond to AM signals.

6.4 Construction and Calibration of Standard 60 DB Co-ax Pad

The co-ax pad is constructed as shown in Fig. 9 and calibrated by adjusting the spacing between the coils to give 60 db of attenuation. Since both coils are shunted by 50 ohm resistors, the pad has input and output impedance of 50 ohms and is not frequency sensitive for the range 420 to 460 Mc. The pad should be handled carefully as a sharp jar might change the positioning of the coils.

The co-ax pad is checked for calibration by comparison tests with a calibrated signal generator

and a sensitive 440 megacycle receiver. If no receiver is available, the calibration can be checked within two db by comparing the direct signal voltage when the co-ax pad is in series with the standard cables, to the signal voltage when the four resistor pads, totaling 58 db, are in the direct path.

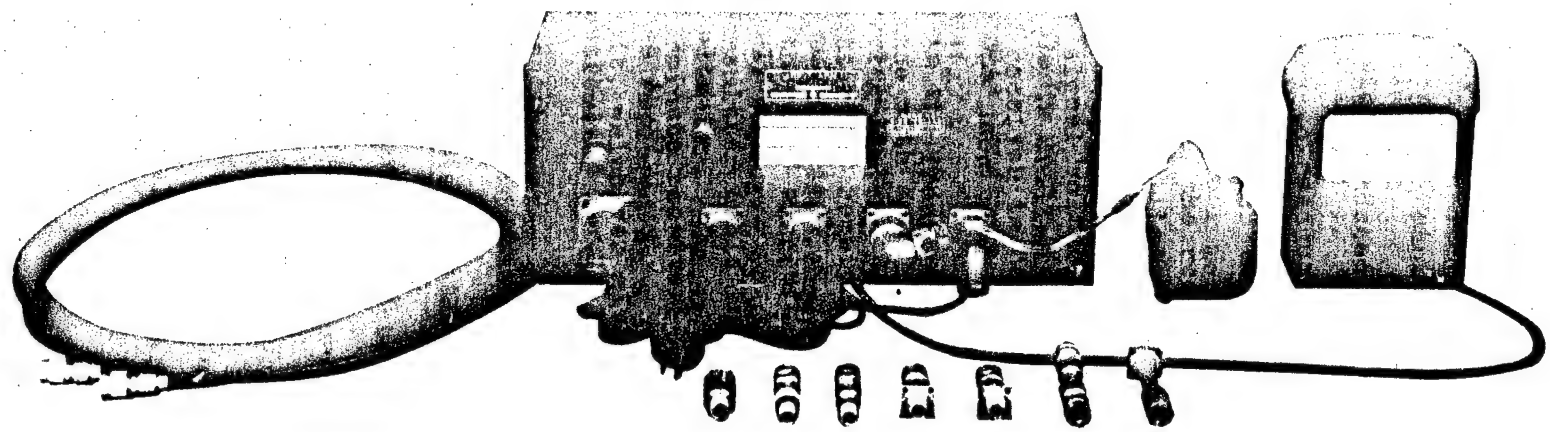


FIG. I, MEASURING EQUIPMENT

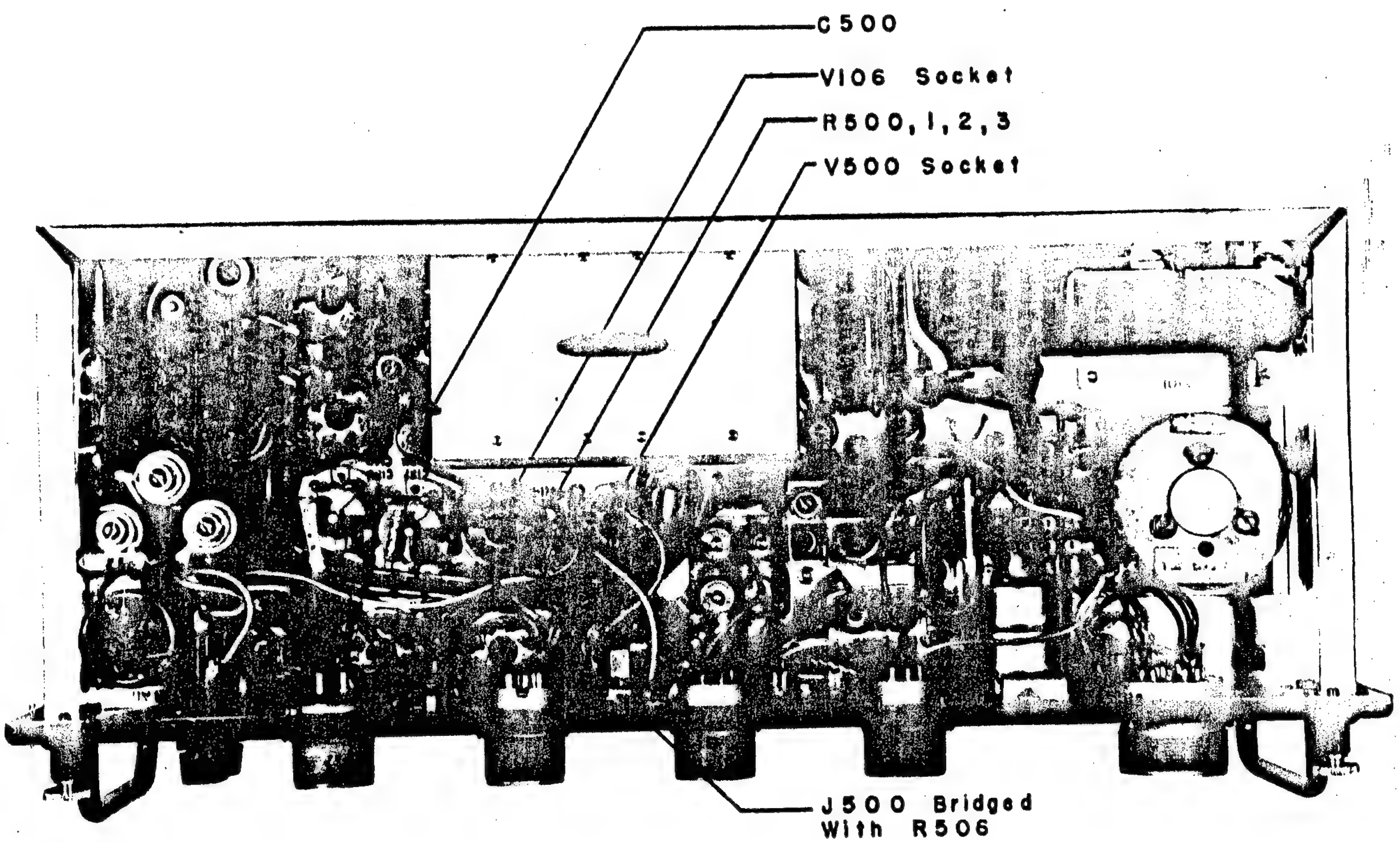


FIG. 2 MODIFIED RT-7/APN-1 CHASSIS

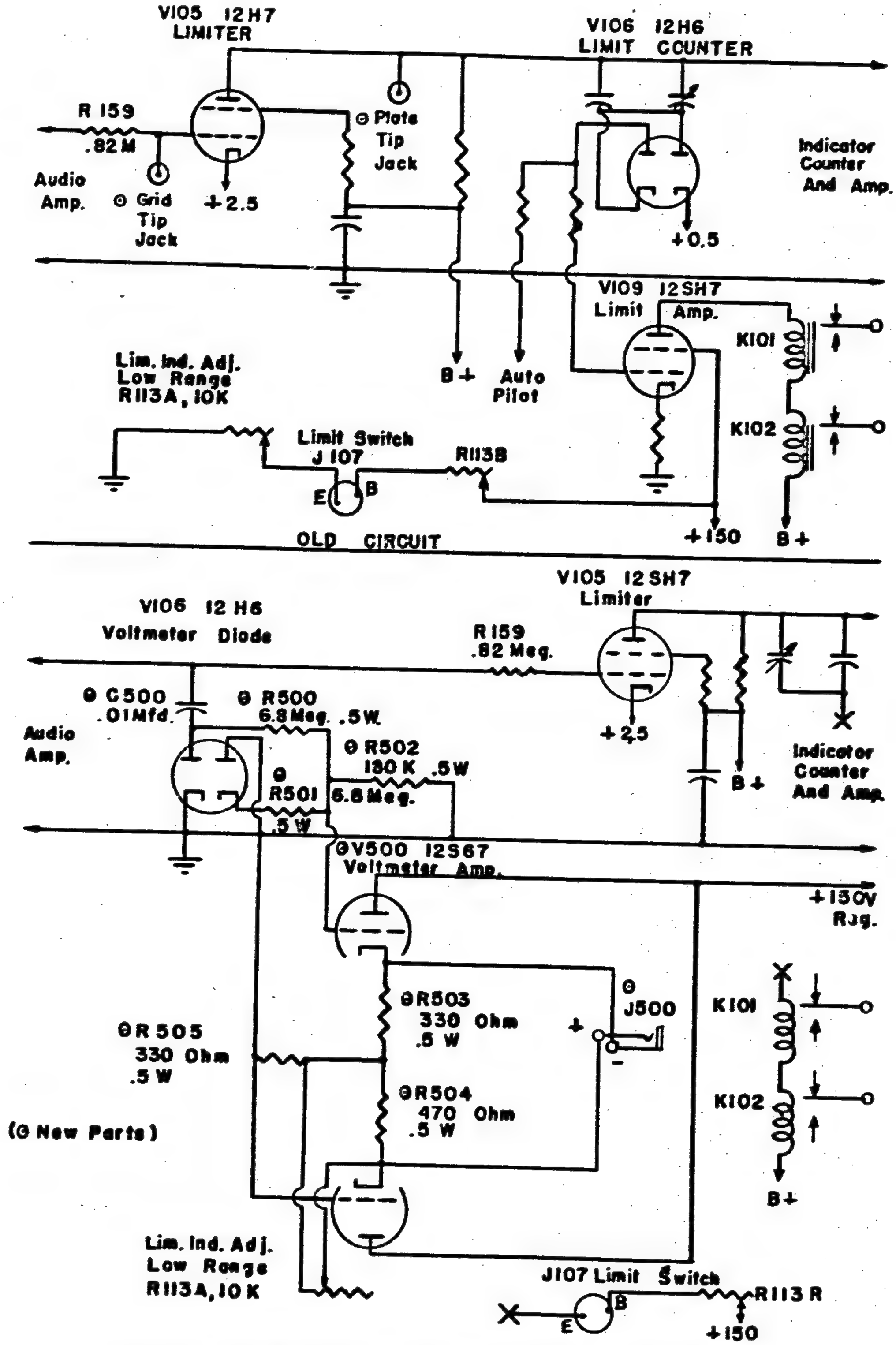


FIG.3 MODIFIED RT-7/APN-1 CIRCUIT

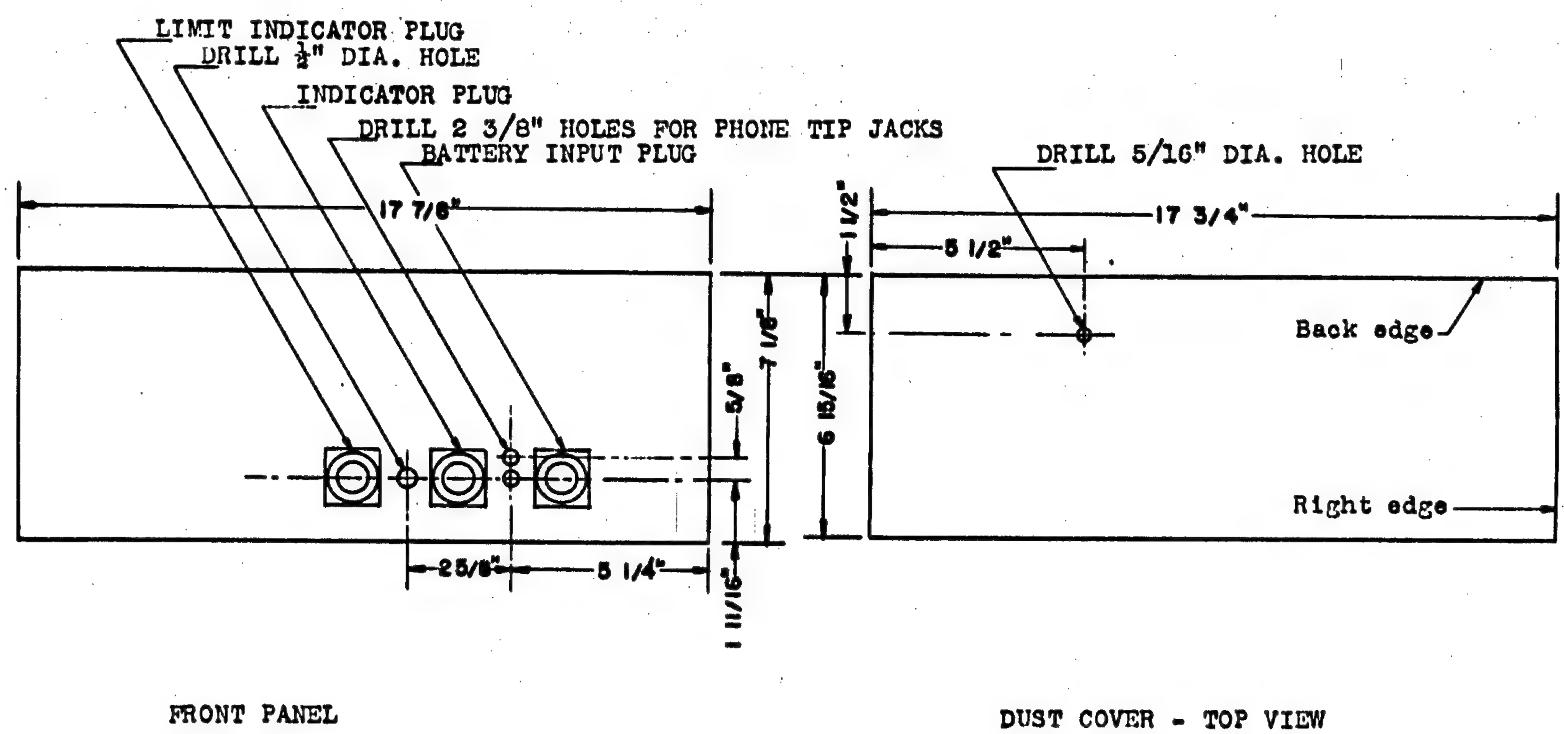


FIG. 4, MODIFIED RT-7/APN-1 PANEL AND COVER

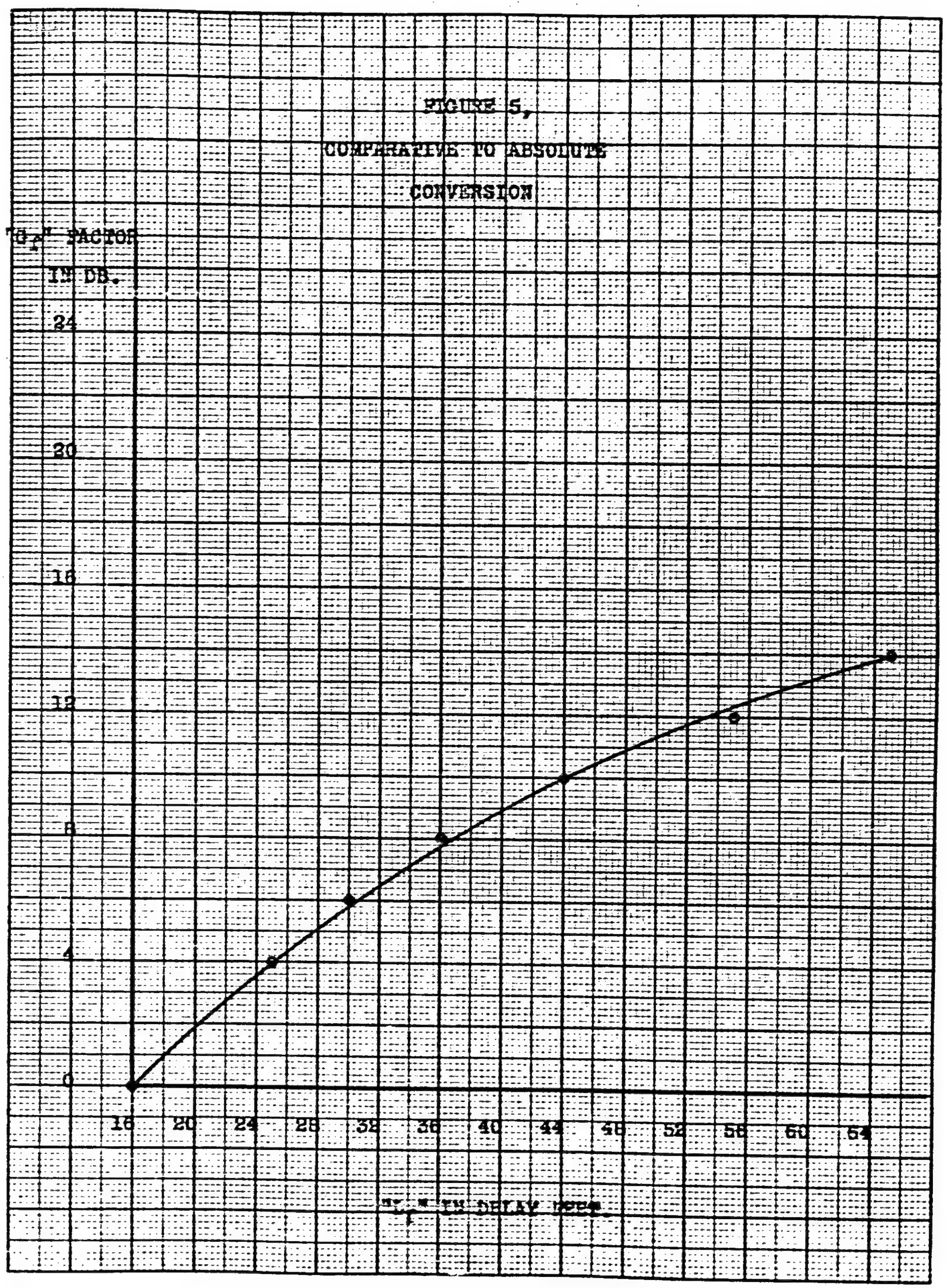


FIGURE 5,
COMPARATIVE TO ABSOLUTE
CONVERSION

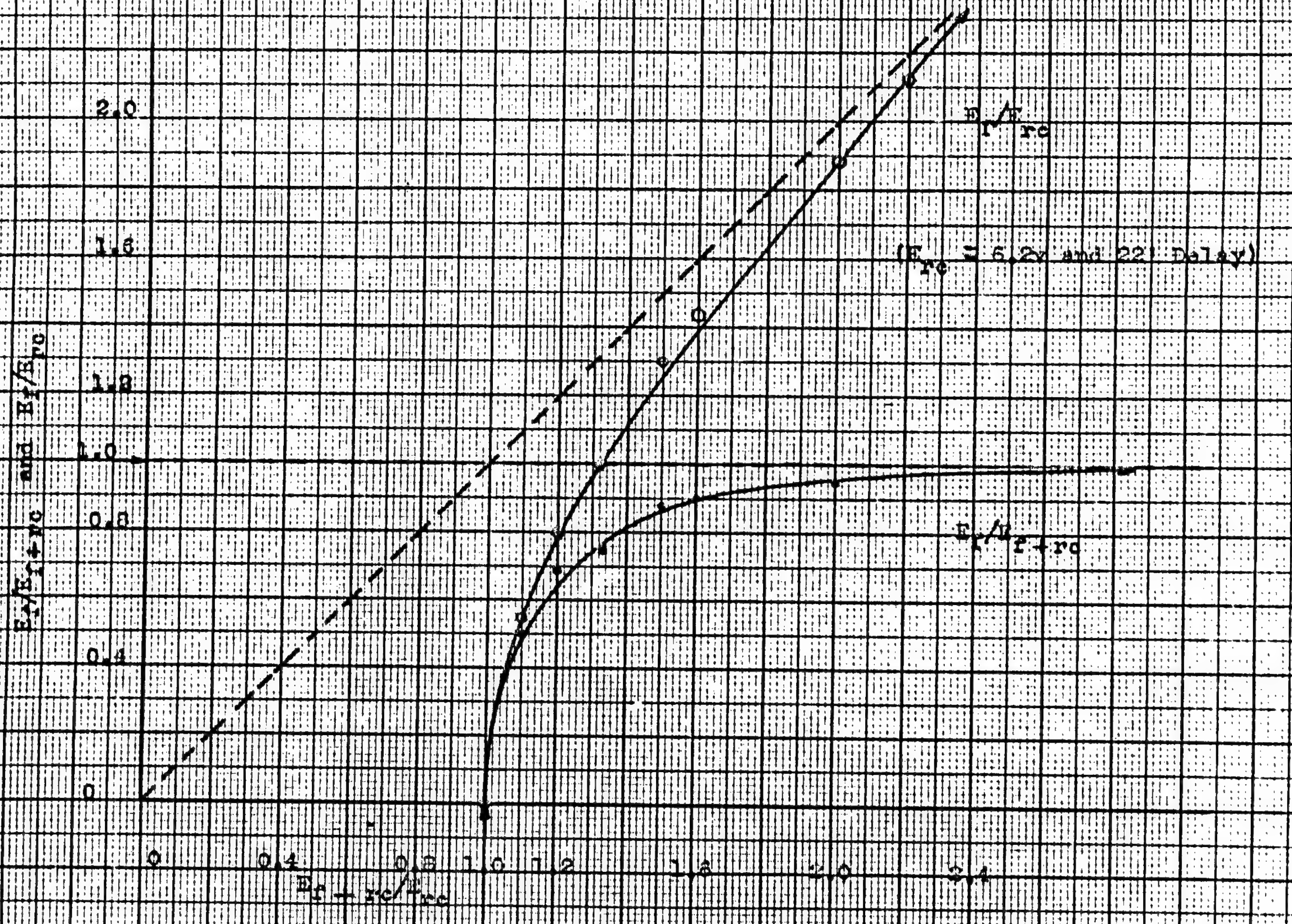


FIG. 6 COMBINATION OF TWO AUDIO SIGNALS, "E_f" and "E_{rc}" UPON N800 VOLTMETER

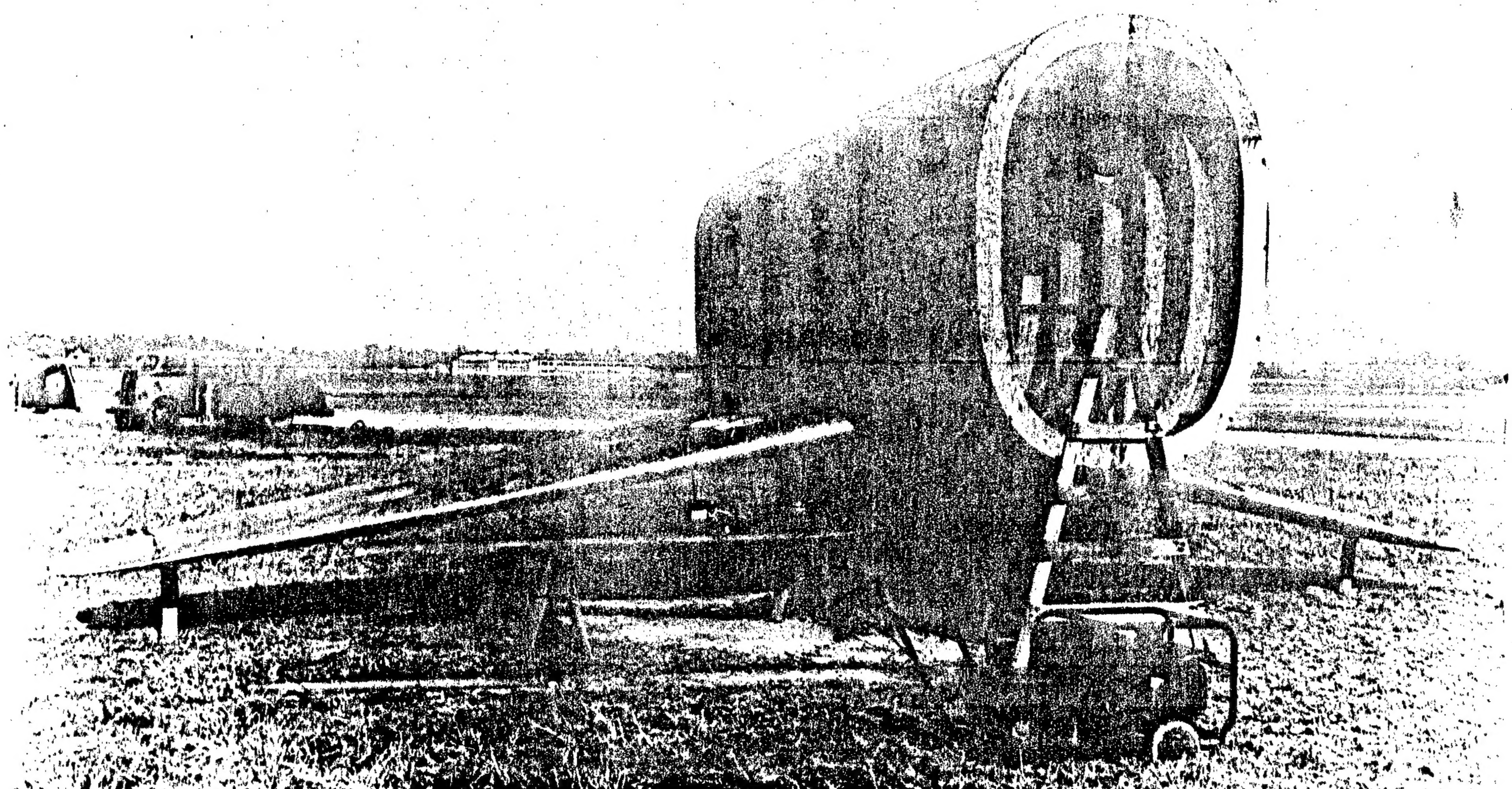
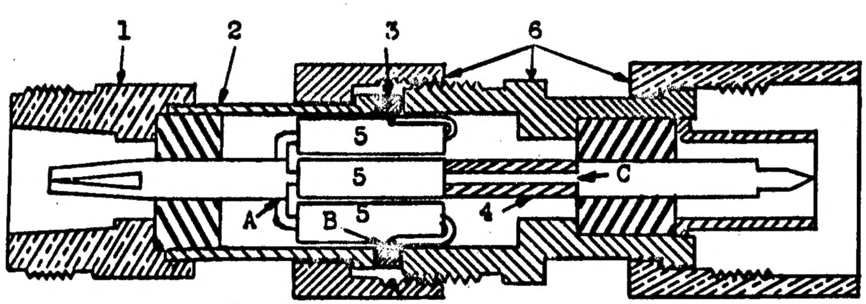


FIG. 7, TYPICAL MOCK-UP TEST

1. UG/58 U Modified
2. UG/21 U Modified
3. Brass Ring
4. Brass sleeve for 20 and 12 db pads only
5. Allen-Bradley Resistors
6. UG/21 U

A. Connection to inner conductor, jack end
B. Connection to outer conductor
C. Connection to inner conductor, plug end



Scale twice size

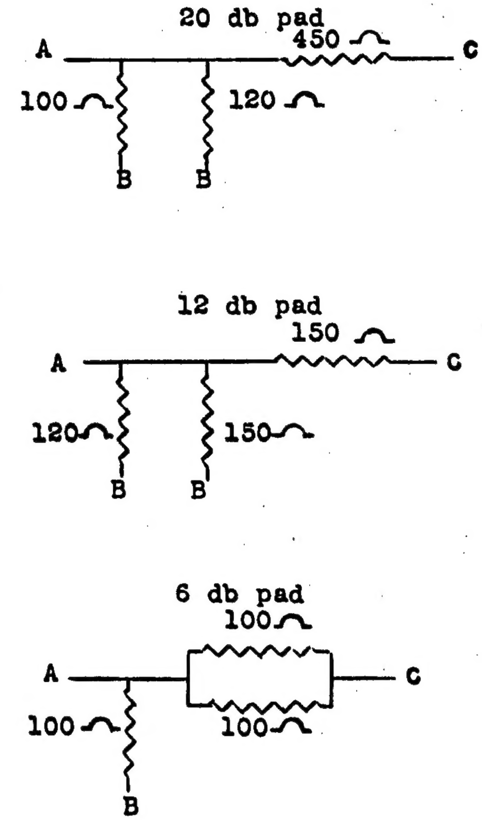
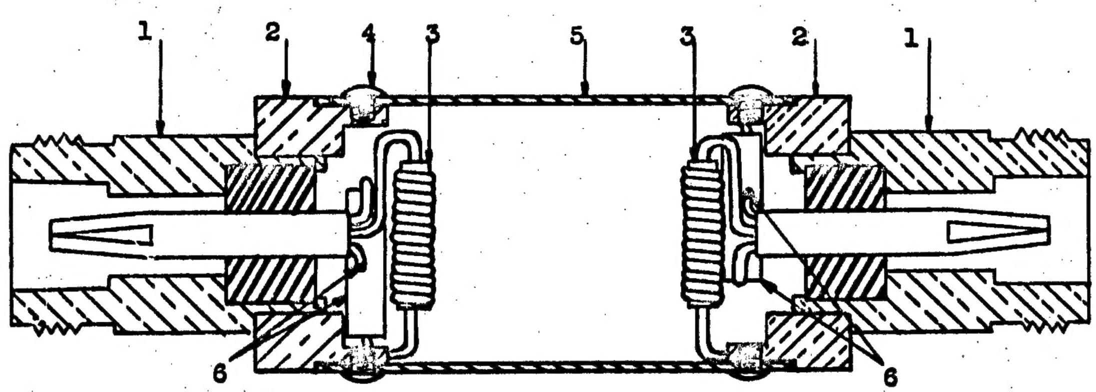


FIG. 8 CONSTRUCTION OF RESISTOR PADS

1. UG-29/U Modified
2. Brass Ring - Press fit to UG-29/U
3. Allen-Bradley 1/2 watt 1 Megohm resistors wound full with #26 enameled copper wire
4. #2 Round head machine screw
5. Brass tube
6. Four Allen-Bradley 1/2 watt 100 ohm resistors, two shunting each end.



Scale twice size

FIG. 9 CONSTRUCTION OF CO-AXIAL PAD

REEL – C

1134

A.T.I.

27804